CHAPTER - 3
ENTITY-RELATIONSHIP MODEL

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DEPSTAR - CE

Outline:

- Design process
- Constraints
- Design issues
- E-R diagrams, Weak Entity Sets
- Extended E-R features- Generalization
- Specialization
- Aggregation
- Reduction to E-R database schema

Design Process:

- The initial phase of database design is to characterize fully the data needs of the prospective database users.
- Next, the designer chooses a data model and, by applying the concepts of the chosen data model, translates these requirements into a conceptual schema of the database.
- A fully developed conceptual schema also indicates the functional requirements of the enterprise. In a “specification of functional requirements”, users describe the kinds of operations (or transactions) that will be performed on the data.

Design Process:

The process of moving from an abstract data model to the implementation of the database proceeds in two final design phases.

- Logical Design – Deciding on the database schema. Database design requires that we find a "good" collection of relation schemas.
  - Business decision – What attributes should we record in the database?
  - Computer Science decision – What relation schemas should we have and how should the attributes be distributed among the various relation schemas?
- Physical Design – Deciding on the physical layout of the database

Design Alternatives:

- A major part of the database design process is deciding how to represent in the design the various types of "things" such as people, places, products, and the like. We use the **term *entity*** to refer to any such distinctly identifiable item.
- In a university database, examples of entities would include instructors, students, departments, courses, and course offerings.
- In designing a database schema, we must ensure that we avoid two major pitfalls:
  1. **Redundancy:** A bad design may repeat information.
  2. **Incompleteness:** A bad design may make certain aspects of the enterprise difficult or impossible to model

The Entity-Relationship Model

- The **entity-relationship** (**E-R**) data model was developed to facilitate database design by allowing specification of an *enterprise schema* that represents the overall logical structure of a database.
- The ER model is very useful in mapping the meanings and interactions of real-world enterprises onto a conceptual schema. Because of this usefulness, many database-design tools draw on concepts from the ER model.
- The ER data model employs three basic concepts:
  - entity sets,
  - relationship sets,
  - attributes.
- The ER model also has an associated diagrammatic representation, the ER diagram, which can express the overall logical structure of a database graphically.

Entity Sets:

- An **entity** is an object that exists and is distinguishable from other objects.
  - Example: specific person, company, event, plant
- An **entity set** is a set of entities of the same type that share the same properties.
  - Example: set of all persons, companies, trees, holidays
- An entity is represented by a set of attributes; i.e., descriptive properties possessed by all members of an entity set.
  - Example:

    instructor = (*ID, name, street, city, salary*)
    course= (*course_id, title, credits*)
- A subset of the attributes form a **primary key** of the entity set; i.e., uniquely identifiying each member of the set.

Entity Sets:

instructor_ID	instructor_name
76766	Crick
45565	Katz
10101	Srinivasan
98345	Kim
76543	Singh
22222	Einstein

instructor

student-ID	student_name
98988	Tanaka
12345	Shankar
00128	Zhang
76543	Brown
76653	Aoi
23121	Chavez
44553	Peltier

student

Relationship Sets:

- A **relationship** is an association among several entities

  Example:

  44553 (Peltier)   *advisor*   22222 (Einstein)

  student entity   relationship set   *instructor* entity

- A **relationship set** is a mathematical relation among $n \geq 2$ entities, each taken from entity sets

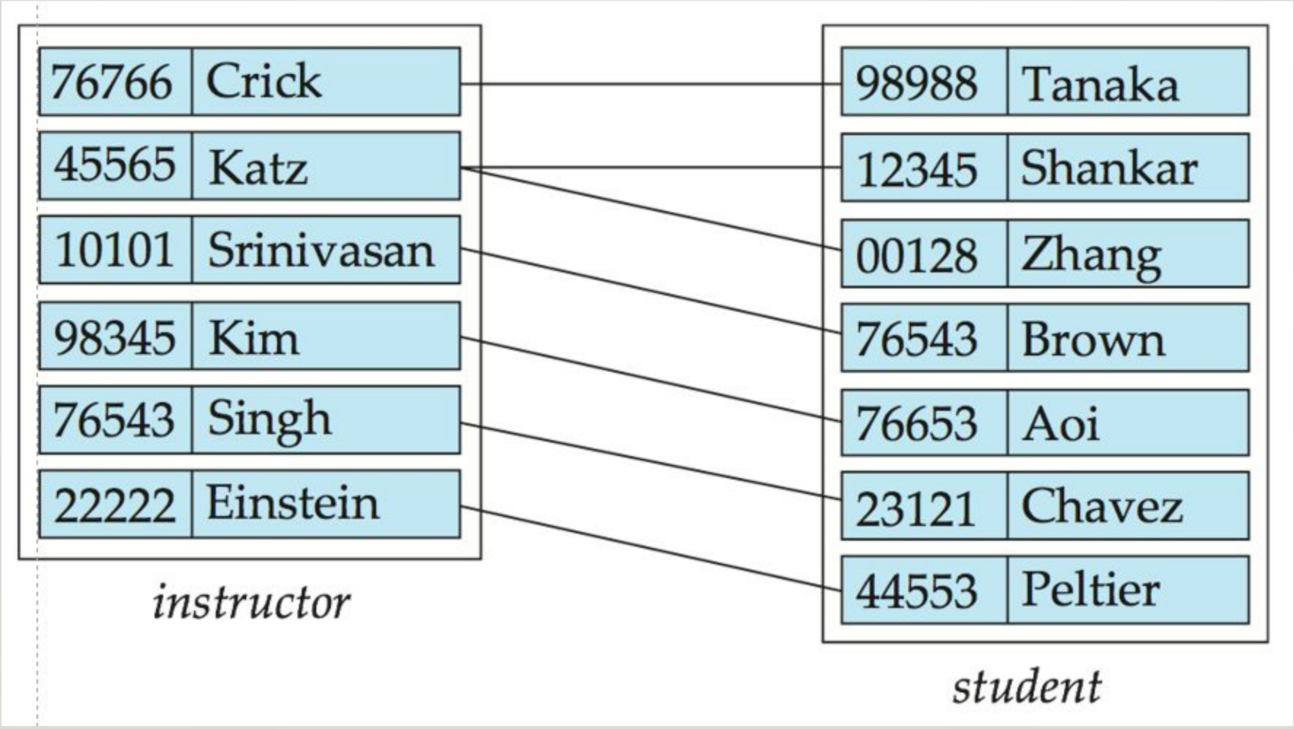
$$\{(e_1, e_2, \ldots e_n) \mid e_1 \in E_1, e_2 \in E_2, \ldots, e_n \in E_n\}$$

  where $(e_1, e_2, \ldots, e_n)$ is a relationship

  - Example:

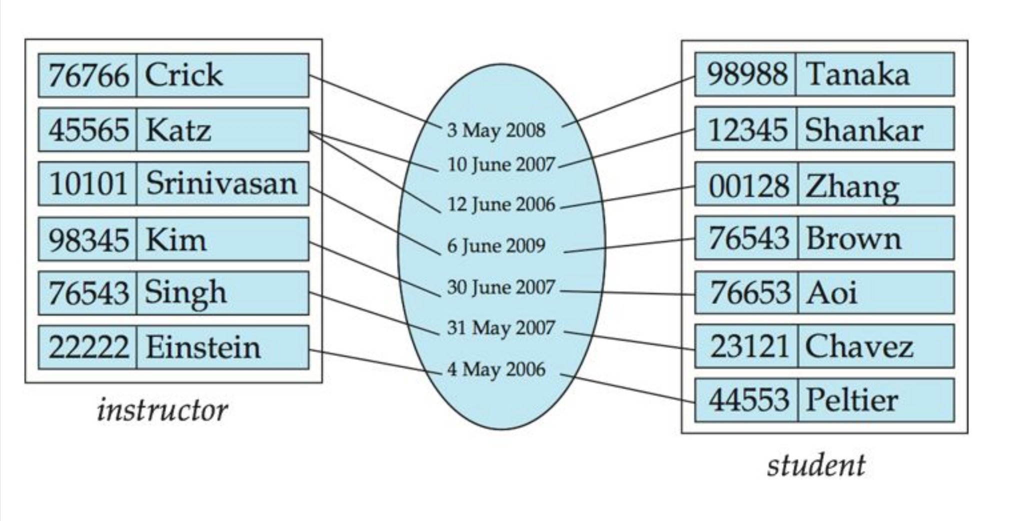
    $(44553,22222) \in advisor$

Relationship Set Advisor:



Relationship Sets:

- An attribute can also be associated with a relationship set.
- For instance, the advisor relationship set between entity sets instructor and student may have the attribute date which tracks when the student started being associated with the advisor



Degree of a Relationship Set:

- binary relationship
  - involve two entity sets (or degree two).
  - most relationship sets in a database system are binary.
- Relationships between more than two entity sets are rare.
- Most relationships are binary. Example: *students* work on research *projects* under the guidance of an *instructor*.
  - relationship *proj_guide* is a ternary relationship between *instructor, student,* and *project*

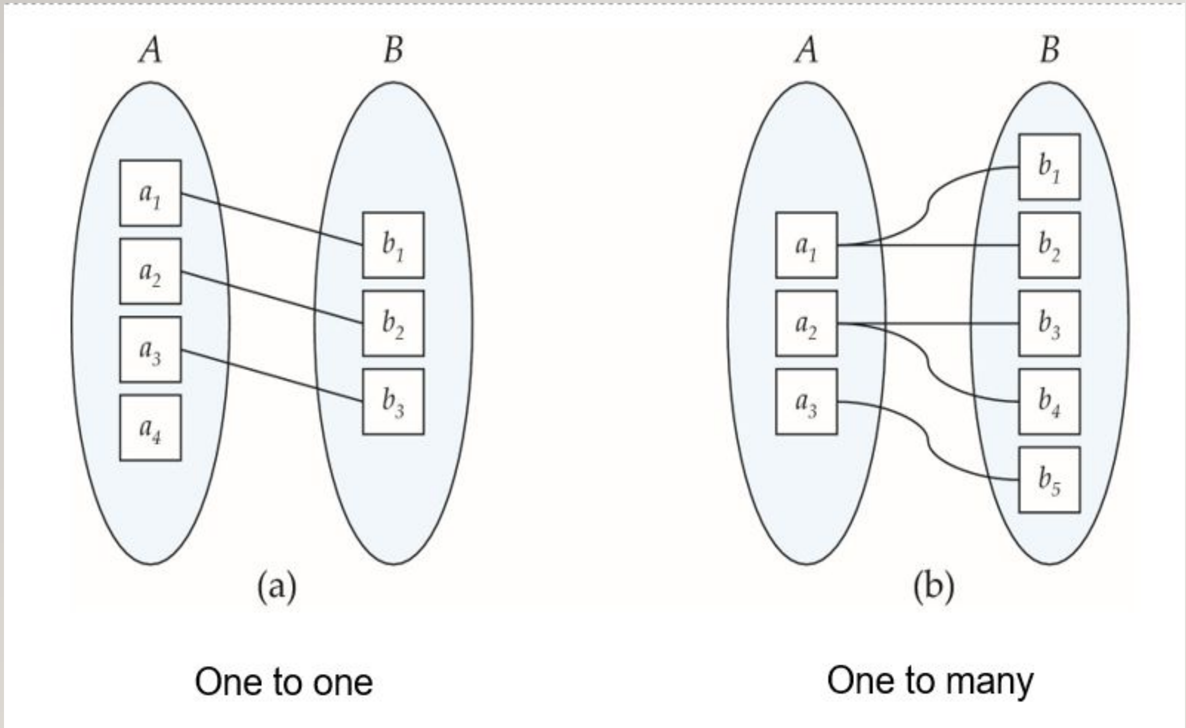
Attributes:

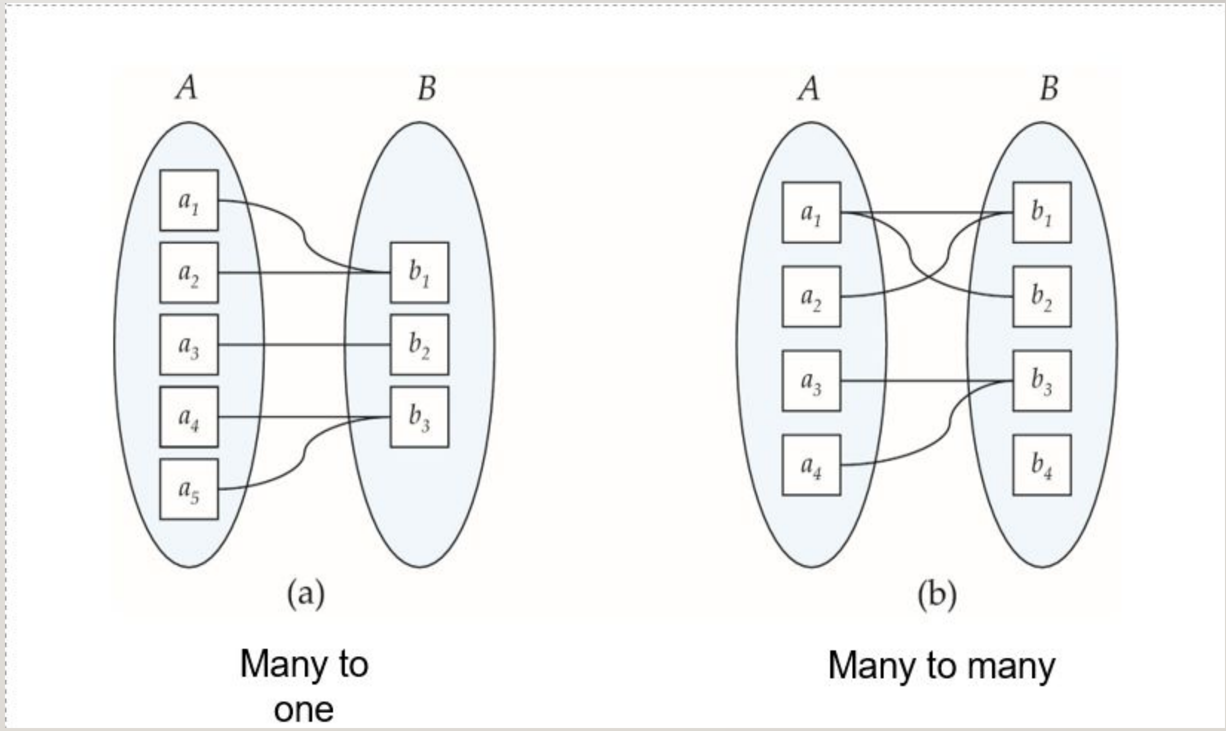
- For each attribute, there is a set of permitted values, called the **domain**, or **value set**, of that attribute. The domain of attribute *course id* might be the set of all text strings of a certain length. Similarly, the domain of attribute *semester* might be strings from the set {Fall, Winter, Spring, Summer}.
- An attribute of an entity set is a function that maps from the entity set into a domain. Since an entity set may have several attributes, each entity can be described by a set of (attribute, data value) pairs, one pair for each attribute of the entity set.
- An attribute, as used in the E-R model, can be characterized by the following attribute types:
  1. **Simple** and **composite** attributes
  2. **Single-valued** and **multivalued** attributes
  3. **Derived** attribute

Mapping Cardinalities:

- Express the number of entities to which another entity can be associated via a relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship set the mapping cardinality must be one of the following types:
  - One to one
  - One to many
  - Many to one
  - Many to many

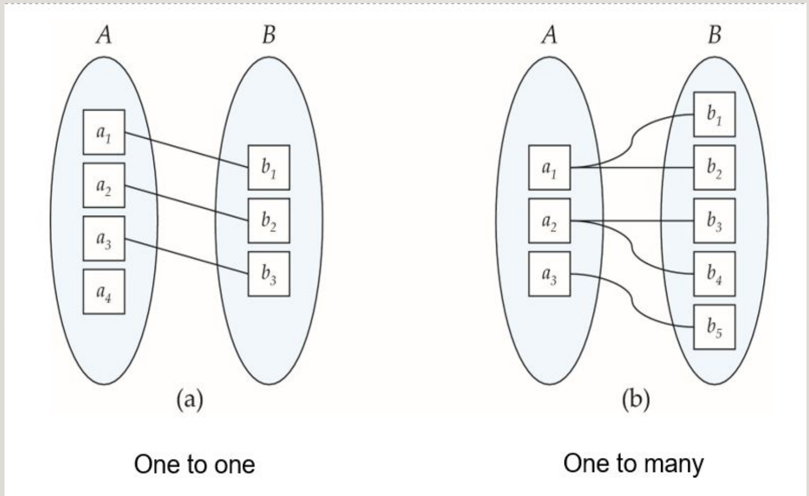
Mapping Cardinalities:





Participation Constraints:

- The participation of an entity set *E* in a relationship set *R* is said to be **total** if every entity in *E* participates in at least one relationship in *R*.
- If only some entities in *E* participate in relationships in *R*, the participation of entity set *E* in relationship *R* is said to be **partial**.

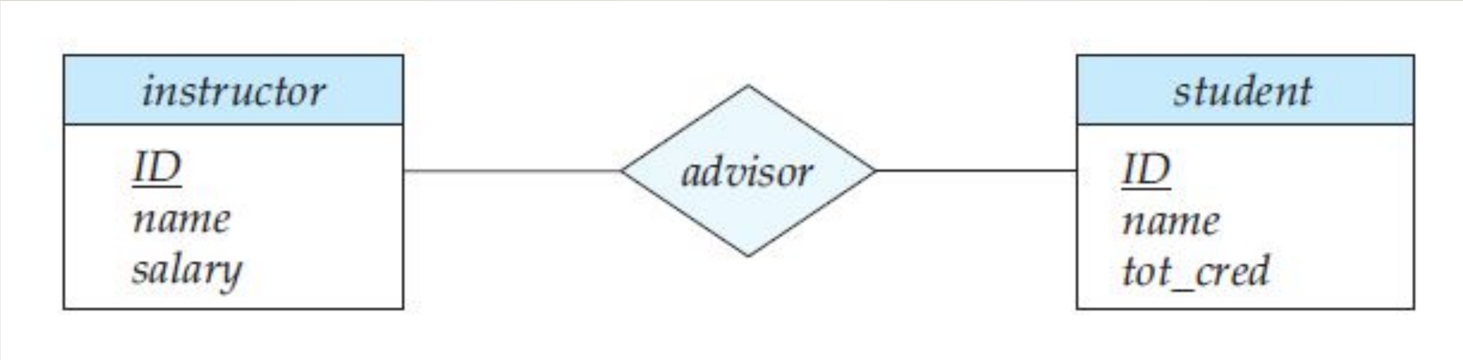


Entity-Relationship Diagrams:

- An **E-R diagram** can express the overall logical structure of a database graphically.
- An E-R diagram consists of the following major components:
- **Rectangles** divided into two parts represent entity sets. The first part, which in this textbook is shaded blue, contains the name of the entity set. The second part contains the names of all the attributes of the entity set.
- **Diamonds** represent relationship sets.
- **Undivided rectangles** represent the attributes of a relationship set. Attributes that are part of the primary key are underlined.
- **Lines** link entity sets to relationship sets.

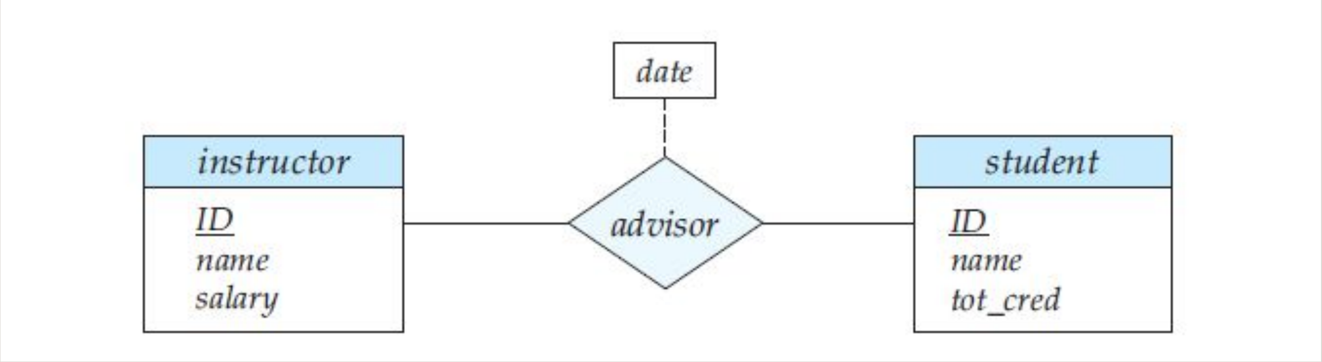
Entity-Relationship Diagrams:

- **Dashed lines** link attributes of a relationship set to the relationship set.
- **Double lines** indicate total participation of an entity in a relationship set.
- **Double diamonds** represent identifying relationship sets linked to weak entity sets



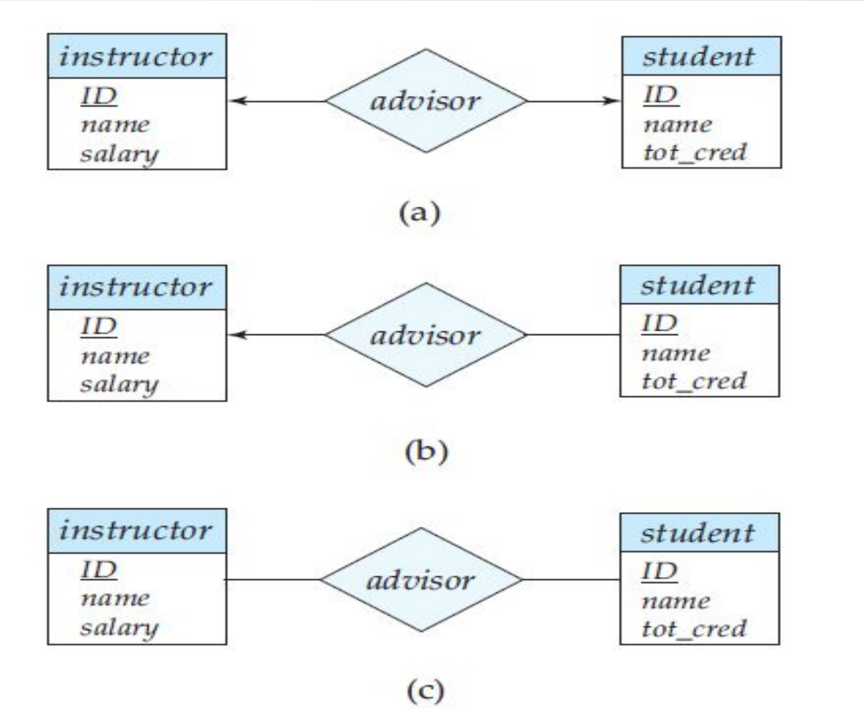
Relationship Sets with Attributes:

- If a relationship set has some attributes associated with it, then we enclose the attributes in a rectangle and link the rectangle with a dashed line to the diamond representing that relationship set.



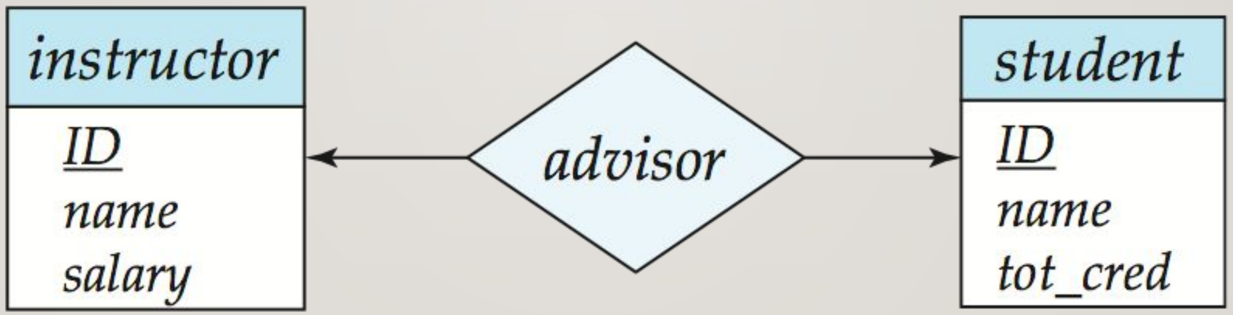
Mapping Cardinality Constraints:

- The relationship set *advisor*, between the *instructor* and *student* entity sets may be one-to-one, one-to-many, many-to-one, or many-to-many.
- To distinguish among these types, we draw either a directed line (→) or an undirected line (—) between the relationship set and the entity set.



One-to-One Relationship:

- One-to-one relationship between an *instructor* and a *student* :
  - A student is associated with at most one *instructor* via the relationship *advisor*
  - A *student* is associated with at most one *department* via *stud_dept*

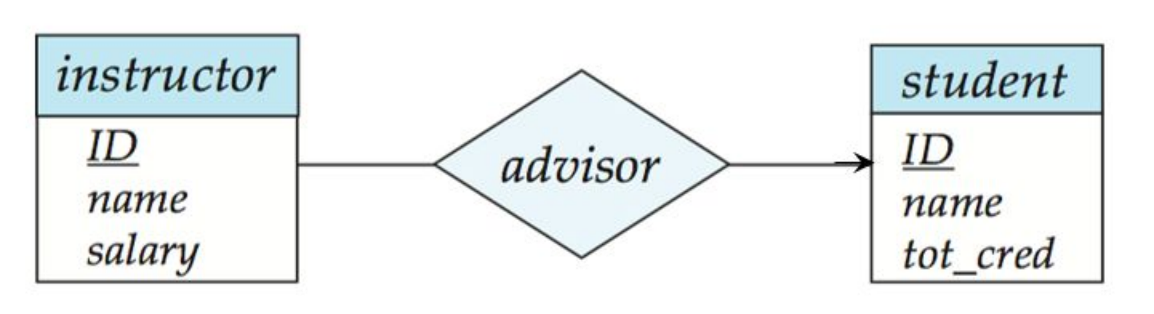


One-to-Many Relationship:

- one-to-many relationship between an *instructor* and a *student*
  - an instructor is associated with several (including 0) students via *advisor*
  - a student is associated with at most one instructor via advisor,

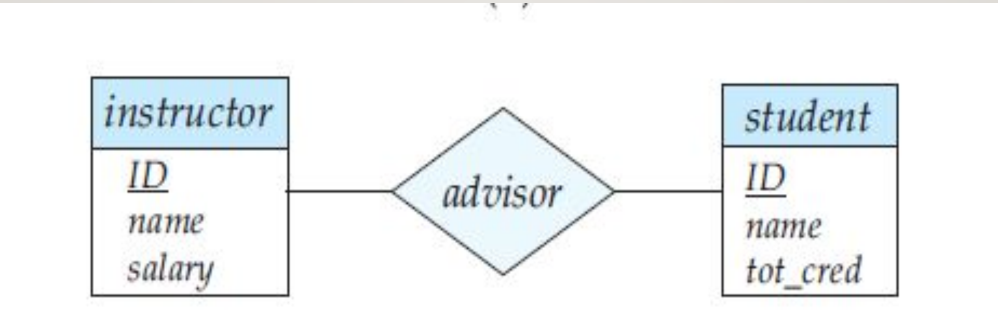
Many-to-One Relationships:

- In a many-to-one relationship between an *instructor* and a *student,*
  - an instructor is associated with at most one student via *advisor*,
  - and a student is associated with several (including 0) instructors via *advisor*



Many-to-Many Relationships:

- An instructor is associated with several (possibly 0) students via *advisor*
- A student is associated with several (possibly 0) instructors via *advisor*



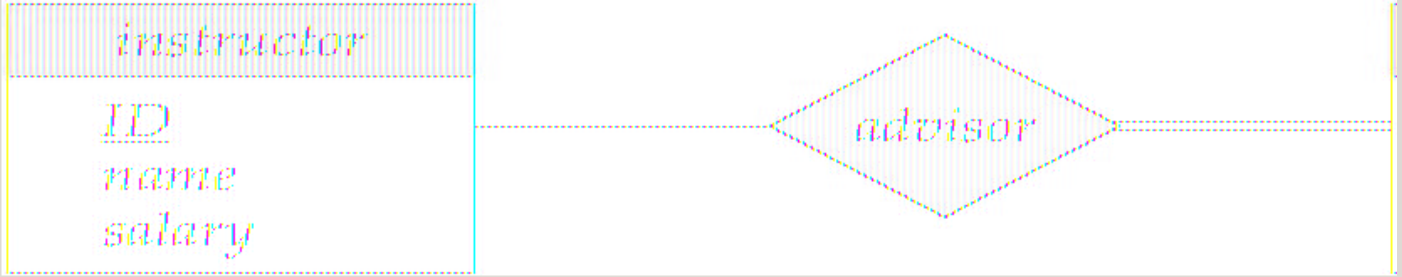
Total and Partial Participation:

- Total participation (indicated by double line): every entity in the entity set participates in at least one relationship in the relationship set

  participation of *student* in *advisor* relation is total

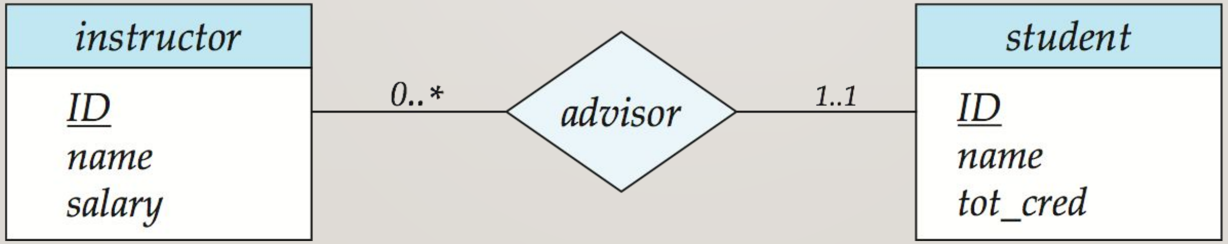
  - every *student* must have an associated instructor

- Partial participation: some entities may not participate in any relationship in the relationship set
  - Example: participation of *instructor* in *advisor* is partial



Notation for Expressing more Complex Constraints:

- A line may have an associated minimum and maximum cardinality, shown in the form *l..h*, where *l* is the minimum and *h* the maximum cardinality
  - A minimum value of 1 indicates total participation.
  - A maximum value of 1 indicates that the entity participates in at most one relationship
  - A maximum value of * indicates no limit.



Instructor can advise 0 or more students. A student must have 1 advisor; cannot have multiple advisors

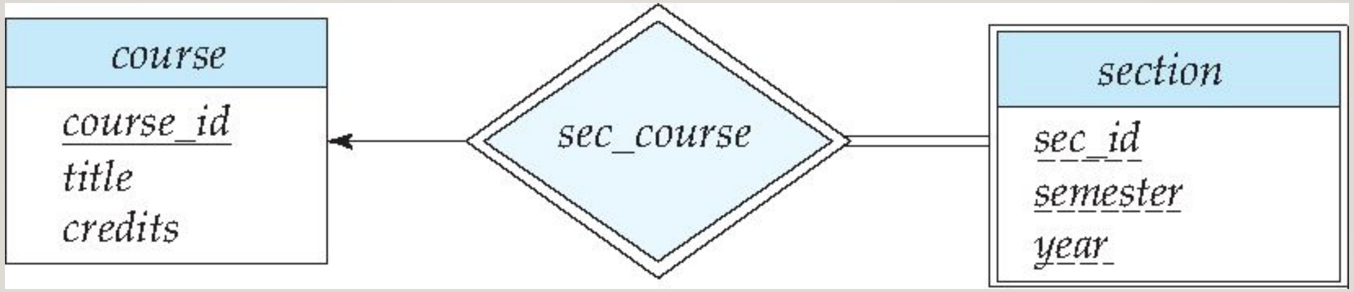
Notation for Expressing more Complex Constraints:

instructor

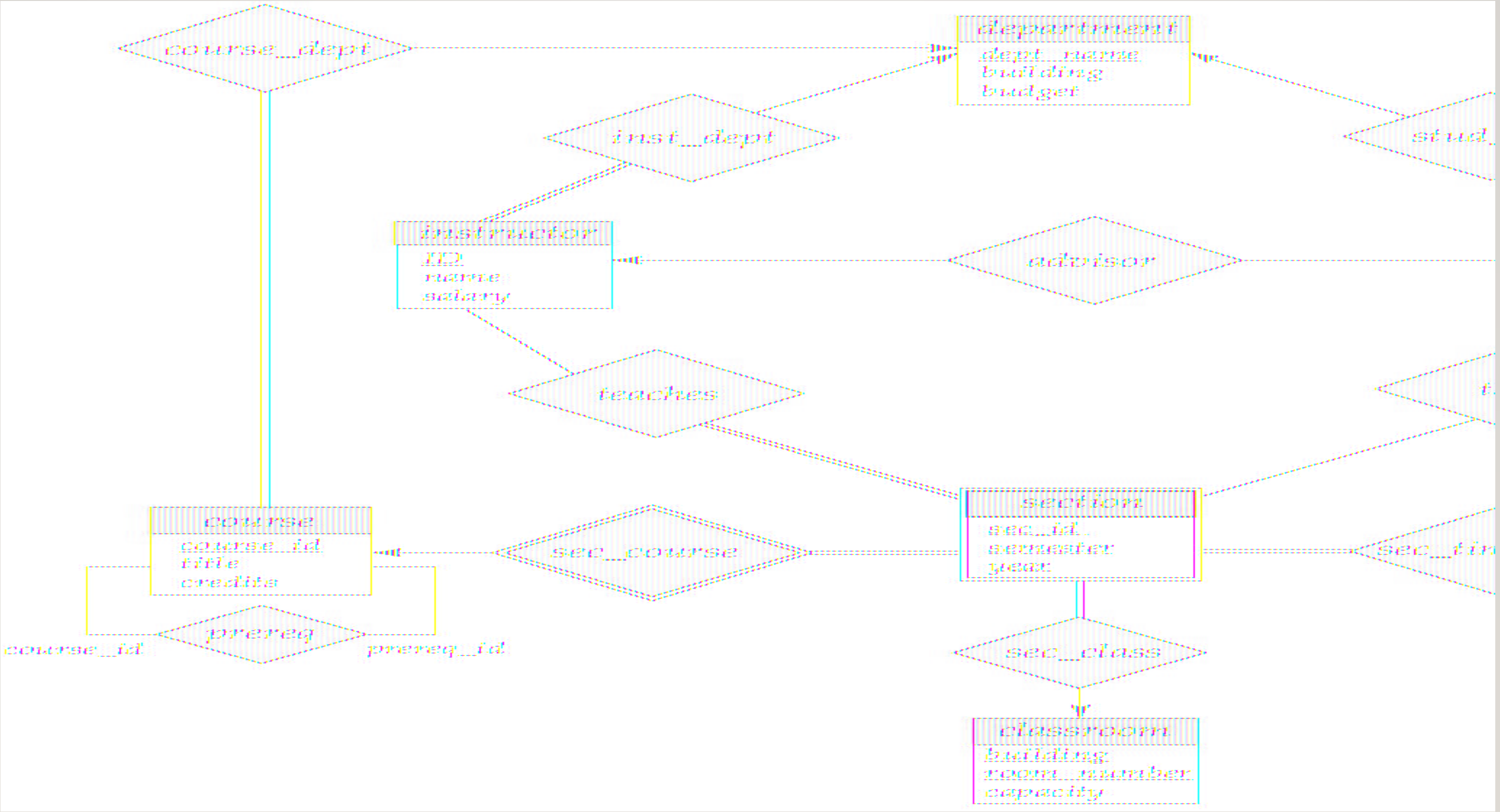
- *ID*
- *name*
  - *first_name*
  - *middle_initial*
  - *last_name*
- *address*
  - *street*
    - *street_number*
    - *street_name*
    - *apt_number*
  - *city*
  - *state*
  - *zip*
- *{ phone_number }*
- *date_of_birth*
- *age ( )*

Expressing Weak Entity Sets:

- In E-R diagrams, a weak entity set is depicted via a double rectangle.
- We underline the discriminator of a weak entity set with a dashed line.
- The relationship set connecting the weak entity set to the identifying strong entity set is depicted by a double diamond.
- Primary key for *section* – (*course_id, sec_id, semester, year*)



E-R Diagram for a University Enterprise:



Reduction to Relation Schemas:

- Entity sets and relationship sets can be expressed uniformly as *relation schemas* that represent the contents of the database.
- A database which conforms to an E-R diagram can be represented by a collection of schemas.
- For each entity set and relationship set there is a unique schema that is assigned the name of the corresponding entity set or relationship set.
- Each schema has a number of columns (generally corresponding to attributes), which have unique names.

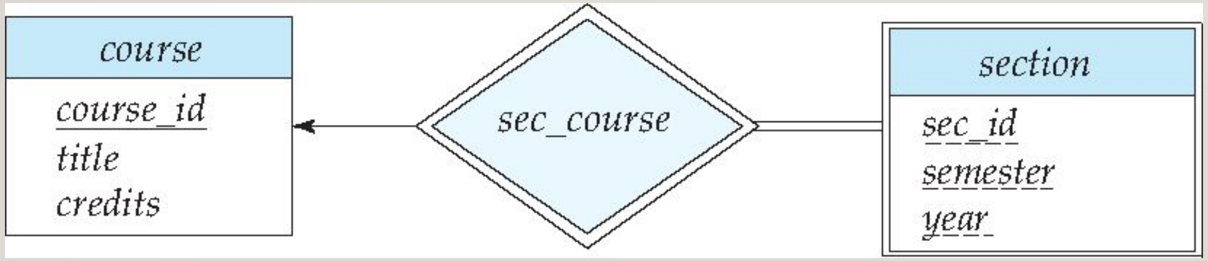
Representing Entity Sets:

- A strong entity set reduces to a schema with the same attributes

  student(<u>ID</u>, name, tot_cred)

- A weak entity set becomes a table that includes a column for the primary key of the identifying strong entity set

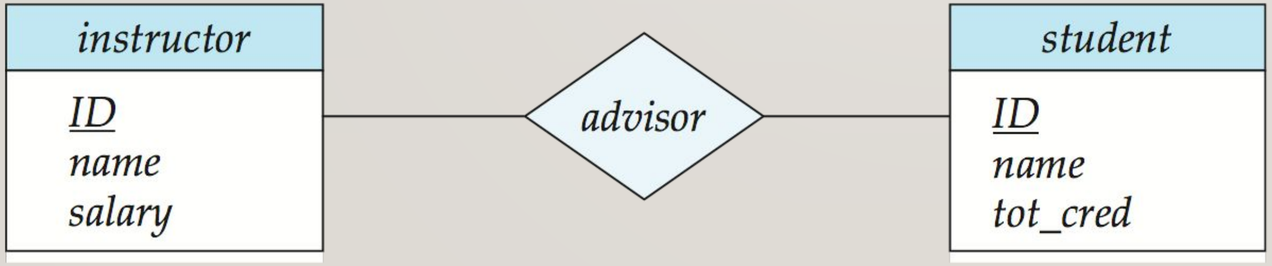
  section (<u>course_id, sec_id, sem, year</u>)



Representing Relationship Sets:

- A many-to-many relationship set is represented as a schema with attributes for the primary keys of the two participating entity sets, and any descriptive attributes of the relationship set.
- Example: schema for relationship set *advisor*

advisor = (<u>*s_id, i_id*</u>)



Representation of Entity Sets with Composite Attributes:

- Composite attributes are flattened out by creating a separate attribute for each component attribute
  - Example: given entity set *instructor* with composite attribute *name* with component attributes *first_name* and *last_name* the schema corresponding to the entity set has two attributes *name_first_name* and *name_last_name*
    - Prefix omitted if there is no ambiguity (*name_first_name* could be *first_name)*
- Ignoring multivalued attributes, extended instructor schema is
  - *instructor(ID,*
    first_name, middle_initial, last_name,
    street_number, street_name,
    apt_number, city, state, zip_code,
    date_of_birth)

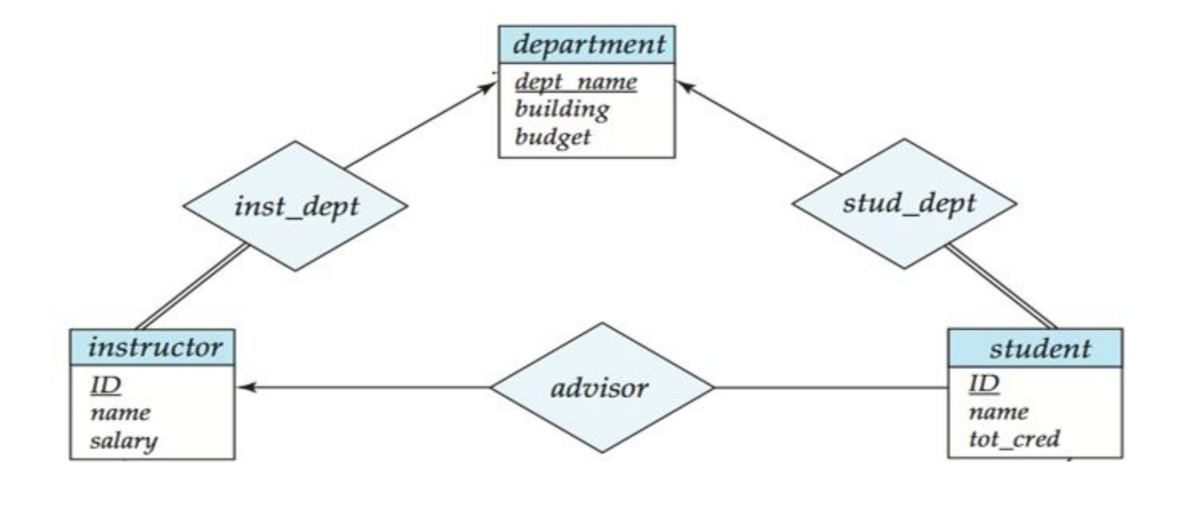
instructor
ID
name
first_name
middle_initial
last_name
address
street
street_number
street_name
apt_number
city
state
zip
{ phone_number }
date_of_birth
age ( )

Representation of Entity Sets with Multivalued Attributes:

- A multivalued attribute *M* of an entity *E* is represented by a separate schema *EM*
- Schema *EM* has attributes corresponding to the primary key of *E* and an attribute corresponding to multivalued attribute *M*
- Example: Multivalued attribute *phone_number* of *instructor* is represented by a schema:
  inst_phone= (<u>*ID*</u>, <u>*phone_number*</u>)
- Each value of the multivalued attribute maps to a separate tuple of the relation on schema *EM*
  - For example, an *instructor* entity with primary key 22222 and phone numbers 456-7890 and 123-4567 maps to two tuples:
    (22222, 456-7890) and (22222, 123-4567)

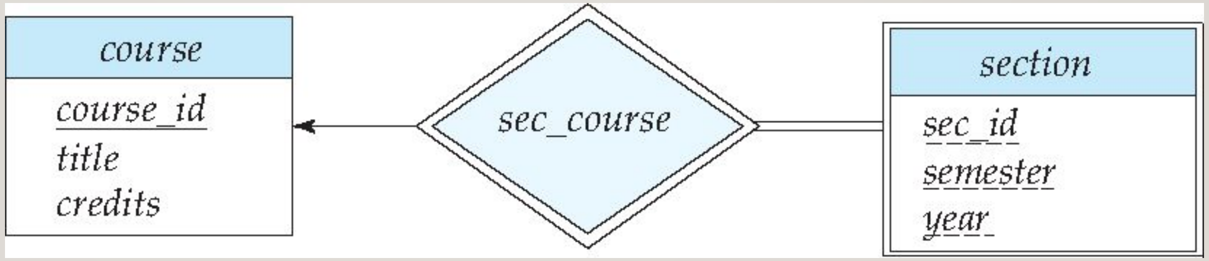
Redundancy of Schemas:

- Many-to-one and one-to-many relationship sets that are total on the many-side can be represented by adding an extra attribute to the "many" side, containing the primary key of the "one" side
- Example: Instead of creating a schema for relationship set *inst_dept*, add an attribute *dept_name* to the schema arising from entity set *instructor*



Redundancy of Schemas:

- For one-to-one relationship sets, either side can be chosen to act as the "many" side
  - That is, an extra attribute can be added to either of the tables corresponding to the two entity sets
- If participation is *partial* on the "many" side, replacing a schema by an extra attribute in the schema corresponding to the "many" side could result in null values
- The schema corresponding to a relationship set linking a weak entity set to its identifying strong entity set is redundant.
- Example: The *section* schema already contains the attributes that would appear in the *sec_course* schema

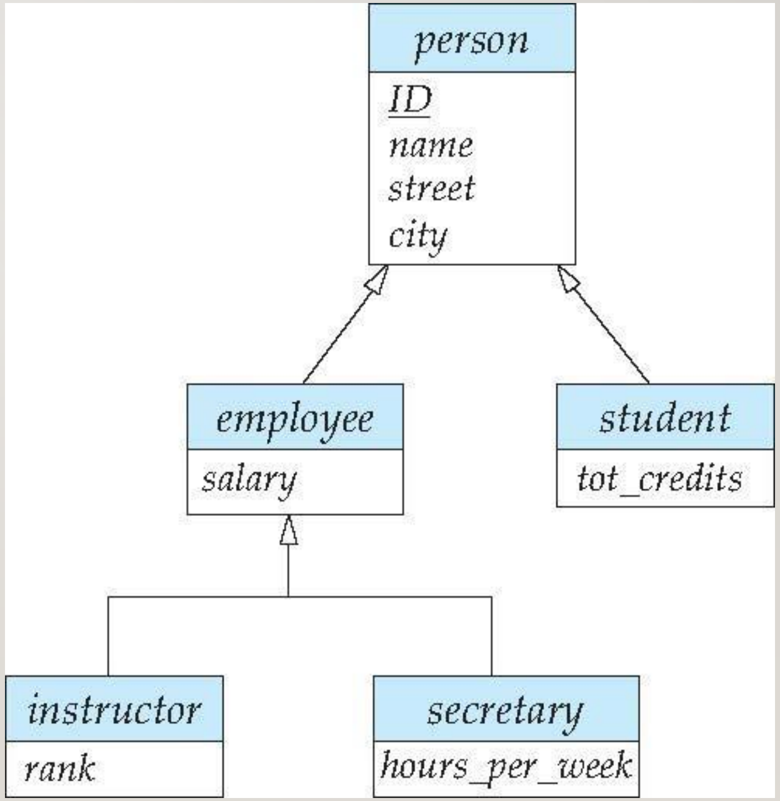


Specialization:

- Top-down design process; we designate sub-groupings within an entity set that are distinctive from other entities in the set.
- These sub-groupings become lower-level entity sets that have attributes or participate in relationships that do not apply to the higher-level entity set.
- Depicted by a *triangle* component labeled ISA (e.g., *instructor* "is a" *person*).
- **Attribute inheritance** – a lower-level entity set inherits all the attributes and relationship participation of the higher-level entity set to which it is linked.

Specialization Example:

- **Overlapping** – *employee* and *student*
- **Disjoint** – *instructor* and *secretary*
- Total and partial



Representing Specialization via Schemas:

- Method 1:
  - Form a schema for the higher-level entity
  - Form a schema for each lower-level entity set, include primary key of higher-level entity set and local attributes

schema	attributes
person	ID, name, street, city
student	ID, tot_cred
Employe	ID, salary

  - Drawback: getting information about, an *employee* requires accessing two relations, the one corresponding to the low-level schema and the one corresponding to the high-level schema

Representing Specialization via Schemas:

- Method 2:
  - Form a schema for each entity set with all local and inherited attributes

schema	attributes
person	ID, name, street, city
student	ID, name, street, city, tot_cred
Employee	ID, name, street, city, salary

  - Drawback: *name, street* and *city* may be stored redundantly for people who are both students and employees

Generalization:

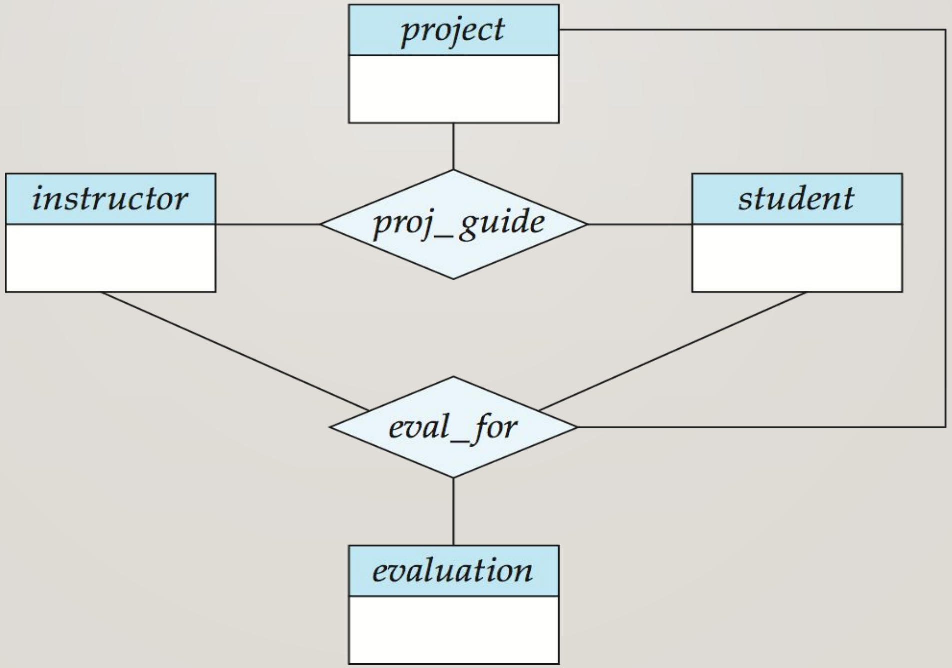
- **A bottom-up design process** – combine a number of entity sets that share the same features into a higher-level entity set.
- Specialization and generalization are simple inversions of each other; they are represented in an E-R diagram in the same way.
- The terms specialization and generalization are used interchangeably.

Design Constraints on a Specialization/Generalization:

- **Completeness constraint** -- specifies whether or not an entity in the higher-level entity set must belong to at least one of the lower-level entity sets within a generalization.
  - **total**: an entity must belong to one of the lower-level entity sets
  - **partial**: an entity need not belong to one of the lower-level entity sets
- Partial generalization is the default. We can specify total generalization in an ER diagram by adding the keyword **total** in the diagram and drawing a dashed line from the keyword to the corresponding hollow arrow-head to which it applies (for a total generalization), or to the set of hollow arrow-heads to which it applies (for an overlapping generalization).
- The *student* generalization is total: All student entities must be either graduate or undergraduate. Because the higher-level entity set arrived at through generalization is generally composed of only those entities in the lower-level entity sets, the completeness constraint for a generalized higher-level entity set is usually total

Aggregation:

- Consider the ternary relationship *proj_guide*, which we saw earlier
- Suppose we want to record evaluations of a student by a guide on a project

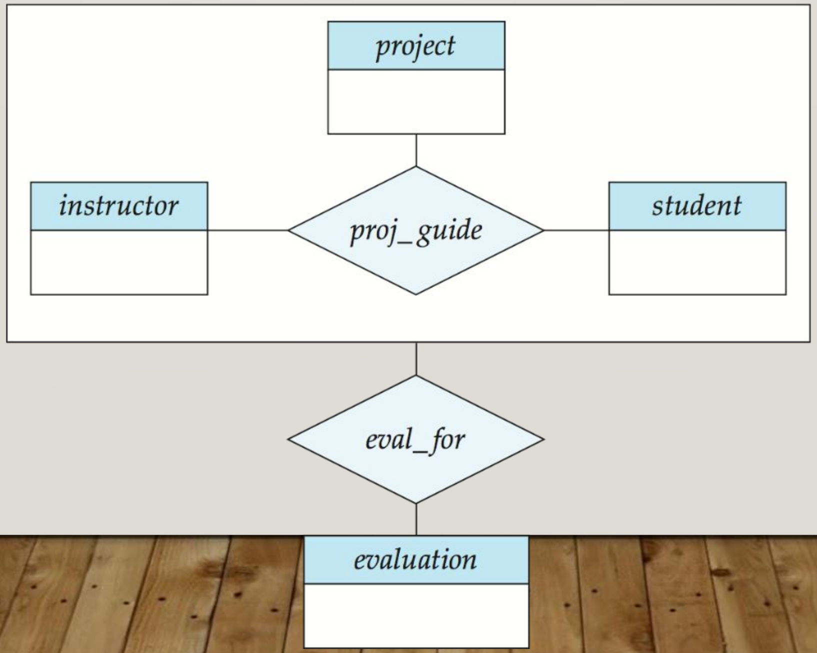


Aggregation:

- Relationship sets *eval_for* and *proj_guide* represent overlapping information
  - Every *eval_for* relationship corresponds to a *proj_guide* relationship
  - However, some *proj_guide* relationships may not correspond to any *eval_for* relationships
    - So we can't discard the *proj_guide* relationship
- Eliminate this redundancy via *aggregation*
  - Treat relationship as an abstract entity
  - Allows relationships between relationships
  - Abstraction of relationship into new entity

Aggregation:

- Eliminate this redundancy via *aggregation* without introducing redundancy, the following diagram represents:
  - A student is guided by a particular instructor on a particular project
  - A student, instructor, project combination may have an associated evaluation



Representing aggregation via schemas:

- To represent aggregation, create a schema containing
  - Primary key of the aggregated relationship,
  - The primary key of the associated entity set
  - Any descriptive attributes
- In our example:
  - The schema *eval_for* is:

    eval_for (*s_ID, project_id, i_ID, evaluation_id*)
  - The schema *proj_guide* is redundant.

Thank You